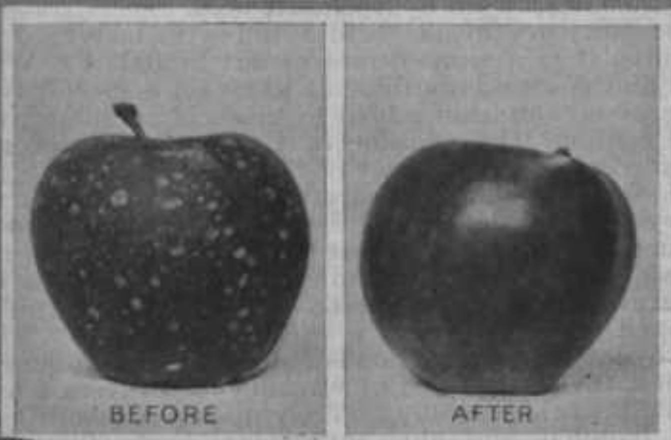
U. S. DEPARTMENT OF AGRICULTURE

FARMERS' BULLETIN No. 1687

REMOVING SPRAY RESIDUE FROM APPLES AND PEARS



PRESENT METHODS of spraying for the control of the codling moth in apples and pears in many sections of the United States frequently result in an arsenical residue on the fruit in excess of the world tolerance of one one-hundredth grain arsenic trioxide per pound of fruit. Oil or lime-sulphur in the spray usually makes it more difficult to remove this residue, while lime in the spray facilitates removal.

Dry-cleaning methods generally can not be depended upon to remove consistently over 30 per cent of the residue from apples. They also involve danger of mechanical injury to the fruit, especially pears. Cloths or brushes used in dry cleaning should be changed frequently.

The use of chemical solvents has been found the most satisfactory method of removing arsenical residue. Commercial hydrochloric acid at the rate of 1 to 4 gallons per 100 gallons of water has generally proved most satisfactory. Exposing the fruit to the acid wash for one-half minute to five minutes, depending upon the type of equipment used, is recommended. A method of testing the acid strength is given. It is desirable to change the acid solution daily or after 1,000 bushels of fruit has been washed. Concentrated hydrochloric acid is very corrosive and must be handled with care.

Alkaline solvents are used in some cases, usually at a temperature of 100° F. or above. Washing fruit with these, however, subjects it to greater danger of injury than washing it with hydrochloric acid.

The efficiency of the acid solution is increased by warming it to a temperature of 80° to 100° F. With fruit that is especially difficult to clean, a special type of kerosene emulsion added to the acid solution gives good results. The addition of 1 to 3 per cent of salt also increases the efficiency of the acid solution.

Thorough rinsing and careful handling of the fruit and systematic changing of the acid solution are essential in safeguarding the fruit against injury. It is not necessary to dry the fruit, although removing some of the excess moisture facilitates packing when fruit is wrapped.

Two simple types of homemade washing equipment are described. The cost of washing varies from 1 to 5 cents a bushel, depending largely upon the quantity of fruit handled and the equipment used. Cleaning, properly done, improves the appearance of the fruit, often makes sorting and grading easier, and does not injure the keeping quality.

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REMOVING SPRAY RESIDUE FROM APPLES AND PEARS

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INTRODUCTION

CONTROL OF THE CODLING MOTH has become essential in the production of marketable apples and pears in practically all deciduous-fruit districts of the United States, and thorough spraying with lead-arsenate has been for many years the accepted control method. Apples and pears sprayed with lead arsenate bear at harvest time an arsenical residue, and this residue must be removed in the interest of public health.

The provisions of the Federal food and drugs act of 1906, as administered by the United States Food and Drug Administration and as accepted by most public-health authorities, do not permit an arsenical residue of more than one one-hundredth grain of arsenic, in the form of arsenic trioxide, per pound of fruit. This limit is commonly called the world tolerance for arsenical residue.

In some districts, particularly in the arid sections of the Pacific Northwest, it has been found desirable to supplement lead arsenate with other spray materials because of the increasing difficulty of controlling the codling moth and in order to reduce the arsenical residue carried by the fruit without diminishing the effectiveness of pest control.

This bulletin proposes to bring together the latest information thus far obtained from experimental work and practical experience on effectively and safely removing spray residue from apples and pears. It is possible, however, that investigations now being con-

[1] The following persons took part in the research upon which this bulletin is based and in assembling the information that it contains, and their assistance and advice are appreciatively acknowledged: D. F. Fisher, Henry Hartman, W. T. Pentzer, J. R. Magness, B. D. Ezell, E. L. Reeves, and L. A. Fletcher, of the Division of Horticultural Crops and Diseases, Bureau of Plant Industry, and J. E. Fahey, of the Insecticide Division, Bureau of Chemistry and Soils, U. S. Department of Agriculture.

ducted by the United States Department of Agriculture and other agencies eventually may develop still more efficient methods than those described herein.

Commercial fruit cleaning has been carried on in some fruit sections for several years, and the consensus of progressive opinion regarding this practice is that when properly done it improves the appearance of the fruit, often makes sorting and grading easier, does not injure the fruit, and may improve its keeping qualities.

RELATION OF SPRAY-RESIDUE REMOVAL TO SPRAYING PRACTICES

Plans for cleaning spray residues from the fruit should start with the beginning of the spraying program in the spring. It may be desirable to arrange if possible for coordinated spraying and fruit-cleaning supervision through the medium of the horticultural inspector's office, the county agent, or some similar agency. In this way the general directions given in bulletins may be adapted to special needs of a particular section, and the fruit industry may be equipped to do the fruit cleaning under a definitely planned program instead of leaving it to the individual grower, whose information may not always be complete or who may not interpret that information to the best advantage. Cooperative action or community effort may thus solve the broad problem, although actual details of fruit cleaning must be carried out by individuals.

It is not possible to determine accurately the cleaning treatment required by the fruit without some preliminary trials and the chemical determination of the residual arsenic on the cleaned fruit. A number of important variables may affect the quantity and character of the spray residue on the fruit at harvest time. Among them are varietal differences; concentration of the lead arsenate used; the spray materials used in combination with lead arsenate; the methods and dates of spray applications; and the weather conditions, particularly rainfall, during the growing season. The time of application of the last spray is important, especially if combination lead-arsenate-oil sprays are used.

In the Pacific Northwest the important apple varieties, when cleaned immediately after harvest, range themselves in about the following order of decreasing difficulty of cleaning, either by washing or by dry cleaning: Esopus Spitzenburg, Arkansas Black, Winesap, King David, Delicious, Stayman Winesap, Jonathan, Yellow Newtown, Rome Beauty, and Winter Banana.

The number of spray applications and the strength of arsenate of lead used should be the minimum required for satisfactory control of the codling moth. Attention of growers is called to the spray recommendations prepared by the various State horticultural authorities or experiment stations. These suggestions are usually designed to aid the grower in obtaining maximum pest control with a residue load that can be removed with the least difficulty.

In the more arid fruit-growing sections, such as the Pacific Northwest, apples or pears sprayed more than three times with lead arsenate in concentrations of not over 2½ pounds to 100 gallons of water usually will require a washing treatment in order to reduce consistently the quantity of arsenic in the spray residue below the world

tolerance for arsenic. The larger the number of applications and the later in the season these applications are made, the greater will be the quantity of spray residue on the fruit at harvest time.

In the Eastern and Middle Western States, because of the great variation in local conditions, it is difficult to determine from the number of spray applications the amount of residue that will be on the fruit when it is harvested. The amount of rainfall and the time of applying the arsenical spray material are the predominating factors in determining the amount of residue. Therefore, to avoid uncertainty, it is very desirable to have a chemical analysis made to determine the amount of spray residue. Fruit carrying the heaviest residue should be selected as the sample for analysis so that the grower may know the worst about his crop. Different varieties, as well as lots that have received different spray applications, should be analyzed separately.

It should be emphasized that omitting late sprays or applying reduced amounts of spray material in an attempt to avoid the necessity of fruit washing may result in heavy losses from wormy fruit, especially in sections where late-brood infestation is severe.

It has been suggested that arsenical dusts be substituted for liquid sprays in order to lessen the fruit-cleaning problem, and in some cases with the hope that washing would not then be necessary. In the arid Pacific Northwest districts dusting is of little value in pest control; but even where it can be employed it generally does not facilitate residue removal. The greatest difficulty has been a greater lack of uniformity in distribution of residue on the fruit where dusting has been tried than in the case of liquid sprays.

Growers using combination lead-arsenate mineral-oil sprays should apply the material soon after it is mixed and not allow it to stand in the tank or in the pipes of a stationary spraying outfit. Very uneven spray residues may result from such delayed application and can be removed only with the greatest difficulty.

Even when spraying is thorough the residue load on fruit taken from different parts of the same tree will show some variation. Rainfall or the use of an overhead-sprinkling system for irrigation may cause a heavier deposit on fruit in the lower portion of the tree because of washing from the upper portions. The drip occurring during the application of spray material is also responsible to a considerable extent for the greater residue load on the lower fruit. When rain or sprinkling water falls directly on the fruit there may be a weathering effect and a reduction in the amount of residue.

The important point in connection with this uneven spray deposit is that although the average residue load on apples or pears from a given tree may be relatively low, and so meet the requirements of the food and drugs act, it is the individual fruits with heavy deposits that often cause trouble. The regulatory officials, in sampling for spray residue, consider as one factor in forming their judgment the fruit showing the heaviest spray residue; therefore, a small quantity of fruit bearing considerable spray residue may endanger the marketability of a whole carload.

The use of spreaders with lead-arsenate spray has not made the residue easier to remove by washing, unless the spreaders contain hydrated lime, nor has it materially reduced blotching on the fruit.

The type of lead arsenate used in spraying does not materially affect the ease of cleaning, provided nothing is added to increase its adhesive qualities. The presence or absence of deflocculators in lead arsenate does not significantly influence the facility with which the fruit is cleaned.

When mineral oils with low volatility and with a viscosity of about 85 seconds Saybolt or more are used with or after applications of lead arsenate, the combined residues generally interfere with cleaning fruit by either dry or solvent methods.

Mineral oil of fairly high volatility and with a viscosity of about 75 seconds Saybolt or less, properly used in combination with lead arsenate, does not significantly interfere with fruit washing if the last application of such combined spray is made some time prior to harvest and if the lead-arsenate residue on the fruit is not excessive. In the Pacific Northwest the last application of combination lead-arsenate mineral-oil spray should be made at least six weeks before harvest. It is possible, through the proper use of mineral oils as spray material, to reduce the quantity of lead arsenate required for effective control so that the amount of arsenical residue will also be materially reduced.

The use of fish oil in combination with lead arsenate tends to make fruit washing more difficult. However, if fish oil is used in the first-brood spray applications and is not used in more than two sprays, the fruit can generally be cleaned without serious difficulty when the acid solvent is used, although it may be necessary to warm the cleaning solution. There is some indication that the alkaline solvents are distinctly helpful in removing residues of combined fish-oil lead-arsenate sprays.

The use of hydrated lime or Bordeaux mixture with lead-arsenate sprays generally facilitates the removal of spray residues when hydrochloric acid is the solvent used in washing. The addition of 1 or 2 pounds of hydrated lime to each 100 gallons of spray in the last two applications will facilitate residue removal and may reduce the arsenical calyx injury that often occurs in some districts because of the formation of water-soluble arsenic. Heavy lime sprays used late in the season in some districts to lessen psylla damage are easily removed with a dilute hydrochloric-acid wash. Solvents other than acid do not effectively remove residues of lime or Bordeaux mixture in combination sprays.

Removing lime-sulphur from fruit has been found difficult. Fortunately, the climatic conditions favoring development of the scab disease for which lime-sulphur is generally used are not especially conducive to the development of the codling moth. The arsenical residues, therefore, are usually not especially heavy in regions where lime-sulphur is used as a summer fungicide, and washing is not often required. Lime-sulphur residue is more effectively removed by dry cleaning (wiping or brushing) than by washing, unless brushes or wipers are used in the washing.

RELATION OF MATURITY TO FRUIT CLEANING

The maturity of the fruit has a marked influence on the facility with which it can be cleaned by any method. All varieties of apples are more easily cleaned at harvest time than after storage. The

development of waxy or oily materials on the surface of the fruit, which makes satisfactory cleaning difficult, apparently takes place throughout the growing season, but becomes very noticeable after harvest, particularly on some varieties of apples, such as Winesap, Arkansas (*Mammoth Black Twig*), Arkansas Black, and Paragon, as the fruit approaches a ripe condition.

Washing immature fruit before the lenticels or pores have been closed with corky tissue may result in injury, particularly in varieties such as Jonathan apples or Bartlett pears. If it is necessary to increase the strength of the solvent, or to warm it, or to prolong the exposure of the fruit to the cleaning solution, there is danger of serious damage through spotting or cracking of the skin.

As the maturing fruit becomes softer it is also more subject to injury by mechanical means and therefore more liable to the development of decay. The sooner the fruit is cleaned after being picked the more easily the cleaning can be done and the less the risk of damage.

In any event, fruit should be cleaned while it is still hard or firm. In order to accomplish this the following practices should be followed: (1) Harvesting at the proper stage of maturity; (2) coordinating the picking and packing operations so that the fruit will be cleaned and packed as soon as possible after it is harvested; (3) holding the fruit in the coolest space available, preferably in cold storage, if cleaning and packing are unavoidably delayed.

CLEANING FRUIT BY WIPING OR BRUSHING

The first commercial efforts to remove spray residue from apples and pears were made with dry-cleaning methods, such as brushing or wiping with cloths. These methods seemed the most simple and convenient and did not involve many changes in the methods of handling the fruit. Figure 1 shows one type of dry-cleaning machine. Experience has shown, however, that when cost, relative cleaning efficiency, safe handling of the fruit, and tonnage capacity are considered, the best dry-cleaning methods are invariably less economical and less satisfactory than suitable washing methods for the removal of spray residue. However, if fruit is cleaned primarily to improve its appearance by removing dust and by polishing, dry cleaning is satisfactory if done with proper care.

Lack of efficiency in dry-cleaning methods is revealed by the results of hundreds of analyses, which indicate that brushing or wiping, under the best conditions, does not consistently remove from apples more than about 30 per cent of the original quantity of spray residue when the residue on uncleaned fruit is not more than 0.04 grain of arsenic trioxide per pound. With heavier original deposits the proportionate amount removed may be greater, but the absolute amount left is often considerably above the world tolerance.

More than half of the arsenical load on apples generally is carried in the calyx and stem ends. Dry cleaning can not effectively remove this residue, which is included in the analysis. Brushing or wiping may, in some cases, actually rub the residue into the waxy coating of the fruit and add more residue to some of the fruits than they bore originally, especially if the cleaning equipment itself is not kept properly clean.

To a certain degree dry cleaning equalizes the amount of spray residue on different apples in the same lot. Therefore, while those with large original deposits may become cleaner under the treatment, those with small original deposits may have more residue added. The brushing or wiping will entirely remove only a relatively small proportion of the residue from all of the fruit, even if the equipment is properly cared for.

Repeated dry cleaning with the same equipment has not materially reduced the quantity of residue below that remaining after one cleaning treatment.

Attempts to increase the rather limited capacity of dry-cleaning machines by hurrying the fruit through them generally result in

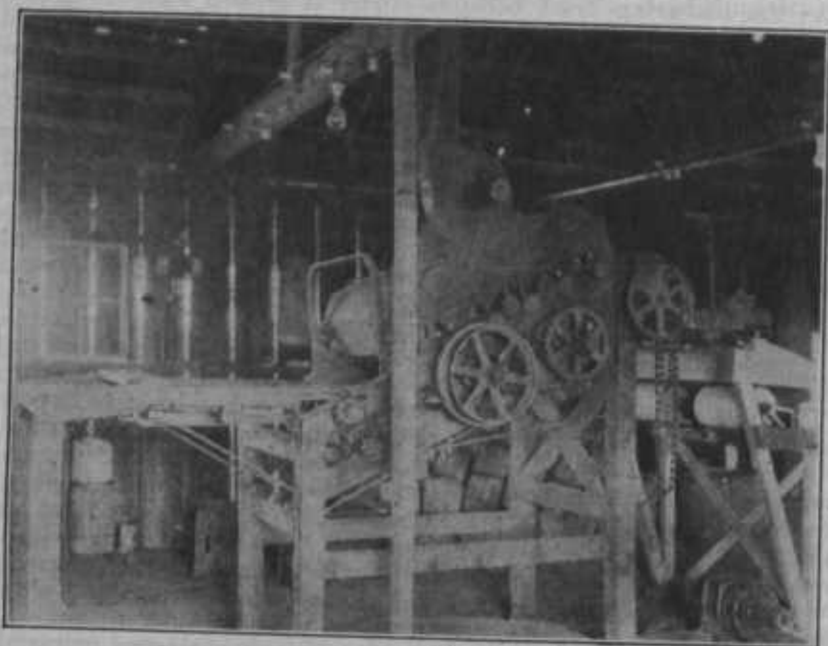

FIGURE 1.—Dry-cleaning machine using cloth wipers

improper cleaning and increase the possibilities of injury to the fruit.

A very decided disadvantage of most dry-cleaning methods under commercial conditions has been that it is practically impossible to constantly adjust the equipment to the size of the fruit. Where the sizes are extremely variable, sorting out extremes before dry cleaning may help to give more uniform cleaning results with less damage to the large fruit. Proper adjustment of dry-cleaning equipment is not always easy, and its lack may cause considerable bruising and other damage.

The efficiency of cloth wipers is determined largely by the rate at which the fruit moves through the machine, by the cleanness and dryness of the cloths, and by suitable adjustment of the cleaning surfaces. The efficiency of brush cleaners is determined largely by the cleanness of the brushes, their ability to retain their original resil-

iency, their proper adjustment in the machine, and the rate at which the fruit moves through the machine.

Using solvents to clean cleaning cloths or brushes while they are in the machine is not satisfactory. Changing the cloths or brushes at least every two hours is essential under ordinary commercial conditions. Some packers discard the old cloths and replace them with new ones; others launder or steam clean the soiled cloths before using them again. Soap and hot water or gasoline are usually available and are effective for cleaning the brushes, especially if applied with a scrubbing brush. At least one extra set of cloths or brushes for replacement while the used ones are being cleaned should be provided.

A suction device for constantly removing loose dust and residue particles from the machine will help materially in keeping the equipment clean.

Under commercial handling and storage conditions there will be very little loss from excessive wilting of the fruit after dry cleaning. However, there is a possibility of loss from slack packs if such fruit is held in storage with a low air humidity. The best relative humidity for apple and pear storage is about 85 per cent.

From the viewpoint of handling, the dry cleaning of pears is generally much less desirable than washing. This is also true to a lesser degree for the more tender skinned apples, such as the Winter Banana. Some types of dry-cleaning equipment are entirely unsuited for pears. In general, any method that subjects fruit to much rolling or contact with parts of the equipment or with other fruit is likely to cause mechanical injury. The use of roller conveyors for certain varieties of pears is also dangerous. The bristles of brush cleaners may puncture the surface of the fruit and allow decay to start.

Hand wiping with sponges or dry cloths or with cloths dampened with water or other solvent liquids is not effective in removing spray residue, and the cost of such a procedure is generally prohibitive.

Oil-soaked rags have been occasionally used in dry-cleaning equipment. Although they impart a high polish to the fruit, they are usually not so effective as dry cloths in removing residue.

CLEANING FRUIT BY SOLVENT METHODS

Several years' experience has shown that arsenical residue can be removed from apples and pears most effectively, cheaply, and safely by the use of some chemical solvent for the lead arsenate. Hydrochloric acid (commonly termed " muriatic acid ") has been found the most satisfactory of all the solvents tested.

Alkaline washes have also been used and are quite effective, but because of the solvent action of some of the alkaline materials on the waxy coating of the fruit their use is often not entirely free from danger of wilting or injury to the fruit. Alkaline washes are generally not very effective in removing residue of sprays containing lime, and an acid wash is to be preferred.

It can not be assumed that any particular washing treatment will clean all fruit regardless of its previous treatment in either spraying or harvesting. Every fruit-cleaning method has its limitations.

The sprays used, as well as their manner of application, may materially modify the facility with which any method will remove spray residue.

Spraying with solvents for arsenical residues while the fruit is still on the tree has been attempted, but has not been found effective in cleaning the fruit and may cause serious injury to the fruit and the tree, as well as to the spraying machinery. Water alone has but little solvent action on arsenical spray residues, and spraying with water or even with soap and water just before picking has invariably proved disappointing.

Any washing method that applies the solvent solution to the fruit by diffused spray, flood wash, or flotation, or by a combination of these, with or without brushes to scrub the fruit, ordinarily gives satisfactory results where necessary precautions are observed.

The ultimate choice of a machine for washing fruit will generally be influenced by the initial cost of the equipment, the cost of operation per unit of fruit, the suitability of the equipment to local conditions, its adaptability to the space available, and particularly to the general mechanical and cleaning efficiency of the machine, as well as the absence of possibility for damage to the fruit.

To prevent the contaminated acid solution from penetrating into the core of the fruit and thereby bringing about decay, machines that use either the direct jet spray or submerge the fruit 4 to 6 inches or more below the surface of the washing solution should be avoided, particularly for apple varieties that frequently have open calyx tubes. These include Jonathan, Esopus Spitzenburg, Stayman Winesap, Ortley, White Pearmain, and sometimes Delicious. Such types of machines are no longer manufactured commercially and should not be constructed by the grower. Immersing the fruit in the cleaning solution while in boxes is open to the same objection as other submersion methods.

A certain amount of agitation is essential in obtaining the greatest efficiency of the dipping method. A slight turning motion of the fruit increases cleaning efficiency in most commercial washing machines of the spray or flood type, but this should not be of such a character as to bruise or injure the fruit. Pears are best handled by conveyors causing a minimum of motion of the individual fruits. This may require the application of the solvent from diffused-spray jets above and below the conveyor in order that the fruit may be covered with solvent on all sides.

"Prewashing" the fruit with water or very dilute solvent ordinarily adds very little to the cleaning efficiency of the operation and is not recommended. Its chief effect is to remove dust and spores of fruit-rot fungi, which are satisfactorily removed by ordinary methods of washing. A distinct disadvantage in the use of the prewash is the constant dilution of the solvent in the washing equipment by carry-over from the prewash. The same dilution may occur when wet fruit is washed.

The strength of the solvent solution should be tested often, the frequency depending upon the conditions prevailing during the treatment. Testing the concentration of the acid washing solution every hour has been found necessary in some cases where such materials as lime or Bordeaux mixture are being removed, because of the

chemical neutralization of the acid by these materials. Note should be kept of the acid strength, analyses, and other pertinent information obtained during the washing process, not only to keep the fruit-cleaning operation of the current season at highest efficiency but also to obtain a record which may be useful in planning the spraying and fruit-cleaning programs of subsequent seasons. Directions for testing the hydrochloric-acid solution are given on page 10.

WASHING WITH HYDROCHLORIC ACID

For removing arsenical spray residues the commercial or technical grade of hydrochloric or muriatic acid is used. The acid should test 20° Baumé, which is equivalent to about 32.1 per cent actual acid. A slight yellow tinge in the acid indicates certain impurities, which, however, do not detract from its value as a cleaning agent.

FIGURE 2.—Carboy-tilting frame to aid in pouring concentrated acid from the large carboys

The acid may be purchased from chemical companies in 10 to 20 gallon carboys, protected by wooden cases, at a cost varying from about 10 to 40 cents a gallon, depending on the quantity purchased and on the distance that the chemical has to be shipped.

Concentrated hydrochloric acid is very corrosive and must be handled with care. It will attack cloth, leather, and some metals unless quickly washed off with water or neutralized by soda, lime, or some other alkaline substance. Therefore, where acid is used for washing fruit, it is desirable to keep on hand a quantity of hydrated lime, carbonate of lime, or common baking soda to be used in case of accident.

If the acid is kept in the carboy, a tilting frame (fig. 2) will be found convenient in pouring it into a smaller container, which should be of glass, porcelain, enamel, or earthenware, preferably in single or multiple gallon dimensions. Great care should be taken in pouring the concentrated acid to keep it from splashing, particularly in drops that might injure the eyes. The fumes of concentrated acid are irritating to the throat and nasal passages, therefore care should be

taken to avert the face somewhat when pouring acid into an open container.

Acid siphon pumps are very useful for transferring the concentrated acid from carboys to smaller containers with a minimum of inconvenience and danger. However, the pump should be removed from the carboy after use, to prevent the acid being accidentally siphoned out of the carboy.

Proper washing of apples and pears generally requires a solution of at least 1 gallon of commercial hydrochloric acid to 100 gallons of water. For average lots of fruit with no particular spray-material complications, 2 to 3 gallons of commercial acid to 100 of water usually are enough. Use of solutions of more than 4 gallons of acid to the hundred is not recommended, because the increase in cleaning efficiency is generally not proportionate to the additional quantity of acid used, and it may considerably increase the cost of washing. The use of such high acid concentrations also places a relatively greater burden on the rinsing section of the washing equipment, and this burden is ordinarily not provided for in the construction of the machines.

A certain amount of the acid solution is carried away on the fruit as it passes through the washer. This loss should be replenished from time to time from a storage barrel filled with cleaning solution of proper strength and arranged to stand beside or over the washing machine. If this loss and the volume of the washing tank are known, the additional acid and water may be added directly to the tank, but this is ordinarily not so convenient as is the method mentioned above.

PREPARATION AND TESTING OF THE ACID SOLUTION

Table 1 is designed for use in connection with the preparation of the acid solution. It may be used either in making up the fresh solution or in increasing the acid strength of the partially spent solution to the desired strength.

TABLE 1.—*Quantities of 20° Baumé commercial hydrochloric acid (containing about 32 per cent actual acid) to be used in preparing solutions of desired strength*

Acid solution desired	Quantity of acid to make indicated quantity of solution														
	100 gallons			150 gallons			200 gallons			270 gallons			300 gallons		
Per cent	*Gal.*	*Qt.*	*Pt.*	*Gal.*	*Qt.*	*Pt.*	*Gal.*	*Qt.*	*Pt.*	*Gal.*	*Qt.*	*Pt.*	*Gal.*	*Qt.*	*Pt.*
0.05	0	0	1¼	0	1	0	0	1	½	0	1	1¼	0	1	1¾
.10	0	1	½	0	1	1¾	0	2	1	0	3	¾	0	3	1½
.20	0	2	1	0	3	1½	1	1	0	1	2	1½	1	3	1
.30	0	3	1½	1	1	1¼	1	3	1	2	2	¼	2	3	½
.40	1	1	0	1	3	1	2	2	0	3	1	1¼	3	3	¼
.50	1	2	½	2	1	¾	3	0	1	4	1	0	4	2	1½
.60	1	3	1	2	3	½	3	3	¼	5	0	¾	5	2	¼
.70	2	0	1½	3	1	¼	4	1	1	5	3	1½	6	2	¾
.80	2	2	0	3	3	¼	5	0	0	6	3	¼	7	2	¼
.90	2	3	½	4	1	0	5	2	1	7	2	¾	8	1	1½
1.00	3	0	1	4	2	1½	6	1	0	8	1	1½	9	1	1¼
1.25	3	3	1¼	5	3	1	7	3	½	10	0	½	11	3	0
1.50	4	2	1½	7	0	½	9	1	1¼	12	2	1½	14	1	0
1.75	5	2	0	8	0	1¾	10	3	1¾	14	3	¼	16	1	1¾
2.00	6	1	0	9	1	1¼	12	2	½	16	3	1½	18	3	½
2.50	7	3	½	11	3	0	15	2	1¼	21	0	1¼	23	2	¼

The strength of the acid solution may be tested during the washing process by a simple titration method. The equipment necessary for this determination may be obtained in most drug stores or can be purchased directly from dealers in chemical supplies. The test requires one 10 c. c. (cubic centimeter) bulb pipette, one 10 c. c. measuring pipette of the Mohr type (graduated to 0.1 c. c.), two ordinary glass tumblers, and a standard solution of sodium bicarbonate consisting of 23 grams of sodium bicarbonate to 1,000 c. c. of water and containing methyl orange indicator sufficient to give a good yellow color. The total cost of the apparatus and solution is generally about $1.

To determine the strength of the acid solution, use the following procedure:

Take a glassful of dilute acid solvent from the washing solution, and from this take a 10 c. c. sample by means of suction on the bulb pipette, allowing the excess to flow from the pipette until the liquid is even with the mark on the upper stem, indicating that the pipette contains 10 c. c. of solution. Allow the measured solution to drain into the second glass. Fill the graduated measuring pipette with standard sodium bicarbonate solution, adjusting the level of the liquid to the 0.0 c. c. mark; then allow the bicarbonate solution to flow slowly from the pipette into the measured sample of acid solvent, all the while gently agitating the latter by shaking the glass or stirring the liquid with a glass rod. As soon as the color of the acid solution changes from red to yellow note the number of cubic centimeters of soda solution that have been used. This number divided by 10 will give directly the percentage of actual hydrochloric acid in the solution being tested. For example, if 6.4 c. c. of the standard sodium bicarbonate solution is used to neutralize 10 c. c. of acid, the strength of the acid will be 0.64 per cent by weight.

To increase this 0.64 per cent solution to 0.75 per cent, for example, it is necessary to add acid to make up the difference of 0.11 per cent. By referring to Table 1 it will be noted that to make 100 gallons of solution having an acid strength of 0.10 per cent, 1 quart ½ pint of 20° Baumé commercial hydrochloric acid is required. The quantity of commercial acid to be added to 100 gallons of water is, therefore, one and one-tenth times 1 quart ½ pint, or 1 quart 1¾ pints. For larger quantities, calculations should be made on the basis of the other figures given in the table. It is readily apparent that the procedure for making up a fresh solution of a given strength will be somewhat simpler.

The bulb pipette should be used only for measuring the acid solution, and it should always be first rinsed with some of the acid to be tested. The measuring pipette should be used only for transferring the standard soda solution to the sample of solvent to be tested.

It will be found useful to keep a permanent record of the acid tests and other data, and for this purpose the following form is suggested. On the reverse side of this form may be printed general fruit-cleaning suggestions.

FRUIT-CLEANING RECORD

MOUNTAIN VIEW GROWERS ASSOCIATION

Packing House No. ------ Machine No. ------

Date	Variety	Grower	Washing-solution test					Washing-solution temperature					Arsenic analysis	Remarks or spray schedule information
			7 a. m.	10 a. m.	1 p. m.	4 p. m.	6 p. m.	7 a. m.	10 a. m.	1 p. m.	4 p. m.	6 p. m.		
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The time required to clean fruit satisfactorily depends upon a number of factors, such as the variety and maturity of the fruit, the amount of residue on it, and the concentration, temperature, and method of applying the acid solution.

In using flotation paddle washers, such as the one described in detail in this bulletin (p. 22), exposing the fruit to the cleaning solution for 3 to 5 minutes is sufficient. In using a dipping method in which there is little agitation of the solvent, five minutes of exposure is generally required. When the solution is pumped or thrown over the fruit in the modified dipping tank, an exposure of 2 to 4 minutes is usually sufficient. In the commercial washing machines 30 to 60 seconds of exposure usually suffices. Prolonging the exposure beyond the times indicated does not generally result in marked improvement in cleaning efficiency, although soaking the fruit in the acid solution may result in slightly greater removal of residue through mechanical loosening of dust and residue particles.

The acid solution and the rinse tanks should be emptied at least once a day, or after about 1,000 bushels of fruit has been cleaned, and an abundance of fresh water should be used to clean them; if necessary they should be scrubbed on the inside. If live steam is available it can be utilized to disinfect the machines and kill accumulated spores of rot fungi. Formaldehyde may also be used as a disinfectant. It may be put into the washing solution and the rinse water at the end of the day, 1 pint of commercial formaldehyde to 100 gallons of water, circulated through the machines, and allowed to remain in the tanks over night. If the tanks and machines are thoroughly cleaned and flushed with fresh water this treatment will not be necessary. No practicable method of disinfecting the fruit during the short period of the washing process has been found.

When the acid-solution tanks are emptied the waste acid should be drained away from stonework, concrete, brick, or iron pipes, which it will attack and corrode in dilute solution. The used solution should be kept out of irrigation ditches and away from trees and other useful plants. A sand pit is an ideal depository for the waste washing solution and also for the overflow from the rinse tank. Where the waste acid must be diverted to sewerage systems, it is well to dilute it with copious quantities of water as it flows into the sewer, and to flush the latter with fresh water after the used solution has passed out.

WASHING WITH ALKALINE SOLVENTS

A number of alkaline materials, including solutions or mixtures of sodium hydroxide, sodium carbonate, trisodium phosphate, borax, or similar substances, generally at temperatures of 100° F. or above, have been used for washing apples and pears.

Sodium hydroxide, commonly called caustic soda, when used alone in concentrations up to 1 per cent by weight, is an effective solvent for arsenical residues where no basic fungicidal residues are involved; but its use is attended with considerable danger unless closely supervised. It is not generally recommended for use by growers or packers in smaller packing establishments, particularly because it makes thorough rinsing very difficult and the caustic soda attacks the waxy coating of the fruit as well as the residue. It

is particularly likely to injure russeted pears and should not be used on such varieties.

Sodium carbonate, commonly called soda ash, or similar milder alkalis may be used with a fair degree of safety in concentrations of about 5 per cent by weight, but their full effectiveness is generally obtained only when the washing solution is warmed to 100° F. or above.

While the cleaning efficiency of the alkaline washes and their satisfactory use when employed under proper supervision and with proper care are fully recognized, experience has indicated that hydrochloric acid is more easily used, is more economical, and is generally preferable for the average grower or packer handling fruit with no particular residue difficulties.

WARMING THE WASHING SOLUTION

Raising the temperature of the acid solution gives increased cleaning efficiency in washing apples from which the residue can not otherwise be satisfactorily removed. The temperature of the solution for this purpose should be at least 80° to 85° F., preferably 90° to 100° for consistently good cleaning. With such temperatures it is often found that without sacrificing cleaning efficiency the acid concentration can be materially reduced below that required when the solution is cold. Often the saving in acid consumption more than compensates for the cost of heating.

The higher temperature in the solution seems to increase to a certain degree the chemical reaction between the lead arsenate and the hydrochloric acid and causes a softening of the waxy or oily materials on the surface of the apple, so that the residue can be more effectively reached by the cleaning solution.

The acid solution at higher temperatures also reacts more rapidly with any metal parts exposed to it, and so the corrosion problem is somewhat increased by warming the washing solution.

Experience has shown that there is no heat injury to mature apples and pears when they are exposed to washing solutions at temperatures of 100° F. or below for periods up to two minutes, nor is there any significant increase in fruit temperature during that time. However, when temperatures higher than about 100° are used for more than two minutes there may be direct immediate injury to the fruit or injury that may appear later in storage.

It is true that lots of fruit are sometimes washed in alkaline or acid washing solutions at temperatures as high as 110° F. It may be possible to do this without injury if the fruit has a waxy coating and if the cleaning operations are closely supervised. However, it is not recommended as safe, particularly for the reason that in order to maintain a considerable volume of washing solution at temperatures around 110° while cold fruit is passing through it is often necessary to raise the solution to much higher temperatures at the beginning of the operation. In such cases also the temperature may go above 110° when the machine is idle and the first lots of fruit going into the washer when operation is resumed may be washed in very hot solutions, with resulting injury to them.

It is not probable that warming the solution will be necessary in order to clean average lots of fruit satisfactorily, unless they carry

excessive arsenical-residue deposits, have received applications of heavy-type oil sprays, or unless their cleaning has been delayed after harvest until they have become very waxy. Under such conditions warming the acid solvent may be very helpful if consistent cleaning to the world tolerance can not be obtained by any other means.

The heating apparatus used should have sufficient capacity to maintain the washing solution at a temperature of at least 80° to 85° F., and temperatures of 90° to 100° may be required if the fruit has been heavily sprayed and is very waxy. Methods of warming the solution are described in the following paragraphs.

CIRCULATION THROUGH COILS

One of the least expensive methods of warming the solution is by circulating it through coils in an improvised stove. An ordinary 50-gallon oil drum, costing about $3 to $5, may be used as a stove by cutting a door in one end, laying it on its side on a fireproof stand (such as a box of sand) and fitting a stovepipe into the upper side. A coil of 1-inch wrought-iron pipe is placed within the drum, bent so that it lines one side and the top of the stove, with the intake at the bottom of the stove and the outlet at the top, thereby favoring the natural circulation of the liquid within the coil. If possible the pipe should be coiled into the desired shape rather than made by the use of fittings. The fewest possible sharp turns in the system, the use of bends in the pipe instead of fittings, and the installation of pipe no smaller and not much larger than 1 inch in diameter will facilitate warming of the liquid and will minimize corrosion. Four or five turns of pipe in the stove should be sufficient, giving about 15 feet of heating coil. Because of the corrosive effect of the warm acid solution it will be necessary to replace the coil occasionally, but this expense should not exceed $5.

In order to convey the cleaning solution from the tank to the heater, the former is tapped near the bottom. A small centrifugal pump of one-eighth or one-fourth horsepower will be sufficient to drive the liquid through the system and will make the heating possible without an excessively high temperature of the acid in the coils, thereby reducing corrosion. To secure circulation in some commercial washing machines one end of the coil can be attached to the pipe carrying the acid from the pump. When convection alone is resorted to for the circulation the temperature of the acid in the coils becomes considerably higher than that in the tank, and the life of the coils is considerably less. A petcock at the highest point in the pipe, which can be opened to allow the escape of entrapped air, will facilitate somewhat the circulation of the liquid where natural circulation only is depended upon.

The total cost of such a system has been from $15 to $20.

Wood has been satisfactorily employed for fuel in the heater. If coal is used, some sort of grate may be necessary. It will usually be necessary to begin circulating and warming the acid solution an hour or two before the cleaning is to begin. This type of heater generally does not have a capacity adequate for the larger sizes of commercial washing machines.

CIRCULATED HOT WATER

A modification of the system described above involves the use of a coil in the cleaning solution as well as in the heater. A water reservoir is provided, usually above the stove, high enough to fill the pipes with water, and a pump is used to circulate the hot water from the coils in the stove through those in the tank. This system is generally satisfactory, and both the pump and the coils will last longer than if the acid solution itself is circulated directly through the heating coil; but the efficiency is obviously not as great as in the system first described.

STEAM COIL

Where a small boiler can be provided economically, or where low-pressure steam is required for other purposes, the solution can be warmed very efficiently by means of a steam coil carrying the steam to the acid-solution tank, which is drilled at the feeding end and at the bottom to receive a 1-inch pipe, preferably of lead, which is fitted to the iron delivery pipe.

It is not necessary to build up a system of several coils in the tank. Usually the pipe is given a turn about the tank and is brought out at the end opposite to that at which it entered. The pipe should preferably rest on cleats in the bottom of the tank. Inlet and outlet valves are provided for controlling the flow of steam through the lead pipe in order to regulate the temperature of the cleaning solution.

RELEASE OF LIVE STEAM

Introducing live steam directly into the liquid has been found a convenient method of warming the acid solution. Condensation of the escaping steam tends slowly to weaken the acid, but this is not an insurmountable difficulty and merely requires closer attention to maintenance of the required acid strength.

ELECTRIC HEATERS

It is now possible to obtain suitably prepared silver-plated electric heaters which can be used for warming the acid solution. These heaters are of the bayonet type and are made in 5 and 8 kilowatt sizes. The local power or electric supply company can usually obtain them. They sell for about $28 for the 5-kilowatt size and $40 for the 8-kilowatt size. For heating a 200-gallon tank, two units, one of each size, should be installed to provide temperatures in the acid solution of at least 80° to 85° F. while cold fruit is being washed. Where higher temperatures are needed two 8-kilowatt heaters probably would be the better installation; for machines with 100-gallon acid-solution tanks one 8-kilowatt heater should provide enough heat. These heaters are so made that by proper wiring either the entire heater or only one-half of it can be used; thus with an 8-kilowatt and a 5-kilowatt heater a range of 13, 10½, 9, 6½, 4, or 2½ kilowatts of electricity for heating is available. It is desirable to split at least one of the units so that if the machine is stopped for

a time the solution can be kept warm enough by allowing part of the heating unit to operate continuously.

The installation of electric heaters usually requires a larger transformer to give the power requirement and, of course, necessitates some extra wiring, all of which increases the expense of heating by this method. The operation of the heaters consumes considerable power, the consumption being fairly close to their kilowatt rating; so if the power rate is high the convenience of this method of heating is more than offset by the additional cost as compared with that of using a stove and coils. The latter equipment also provides more heat for the packing room, which is a factor to be considered in cold weather, when the solution is most likely to be heated.

ADDITIONAL INGREDIENTS IN THE WASHING SOLUTION

KEROSENE EMULSION

Where exceptional difficulty is encountered in washing apples because of heavy spray-oil deposits or much natural waxiness of the skin, the use of a kerosene emulsion added to the regular acid wash has been found helpful. The emulsion found most satisfactory for this purpose is made according to the following formula:

Two and one-third pounds kaolin.
One gallon water.
Two gallons kerosene, preferably the odorless type.

In making this emulsion a good mixing machine is essential. A small power-driven emulsifier or a stirring rod and propeller are satisfactory for this purpose. This equipment is similar to but of a larger size than that used at soda fountains for stirring certain milk drinks. Any large tin or stoneware jar is suitable as a container for the emulsion.

The kaolin is added to the water and allowed to stand for 5 to 10 minutes. The mixer is then placed in the water and the kaolin and water are mixed thoroughly. Finally the kerosene is added slowly with continuous stirring. After the kerosene is all added the stirrer should be run for about two minutes to complete the emulsion.

The emulsion should preferably be made up fresh each time; if this is impracticable it should at least be thoroughly stirred before use.

Kaolin is a colloidal clay and may be obtained from most dealers in clay products. The washed and ground material should be used for making kerosene emulsions. Ordinary emulsions of kerosene made with soap, casein-lime, or casein-ammonia should not be used, since these emulsifiers are attacked by the dilute hydrochloric acid.

The kerosene emulsion will give significantly increased efficiency only when the temperature of the cleaning solution is above 90° F. It should be used at the rate of 1 to 1½ gallons of the emulsion to 100 gallons of cleaning solution. Because of a loss of kerosene due to volatilization and carry-over in commercial washers, it will be found necessary to add about half the original quantity of emulsion after every two hours of continuous operation. This makes kerosene emulsion rather costly and limits its use to fruit that is very difficult to clean.

Use of the kerosene emulsion must be confined to those types of washers in which there is a distinct agitation of the solvent material. Dipping tanks and paddle-type flotation washers do not supply sufficient agitation.

SALT

Addition of 1 to 3 per cent of common salt to the hydrochloric-acid wash in many cases has resulted in much more thorough removal of the lead-arsenate residue. It increased efficiency of both cold and warm solutions, but the relative increase in removal was usually greater in cold solutions. The use of certain concentrations of salt also makes it possible to wash pears in the flotation-type washer, whereas without salt they will sink in the acid solution. No adverse effects on the keeping quality of the fruit as a result of the use of salt have been found.

RINSING THE FRUIT

Proper rinsing of the fruit is a very important part of the washing process and can do much toward eliminating the danger of injury from soluble arsenic, acid burning, and decay. Three methods of rinsing are suggested in the order of their preference.

(1) Use of fresh water only for rinsing is the ideal condition, but can not always be attained where water is scarce and is sometimes made impracticable by the construction of the rinsing section of the equipment, as in the modified paddle washer and dipping tank. Two or three gallons of fresh water to each box or bushel of fruit should be available, should be allowed to flow over the fruit, and then should be discarded.

(2) In the recirculation of part of the rinse water the fresh water is best added as a final spray or flood over the fruit as it leaves the rinsing section, thus giving the fruit the benefit of a final rinse with water in which there is no carry-over of acid, soluble arsenic, or fungus spores. This water then drains into the recirculating tank and is used over again. If possible the first rinse water passing over the fruit as it enters the rinsing section should be discarded. This prevents the larger part of the acid solution and spores on the fruit from being carried into the recirculated rinse water.

(3) If the same rinse water is used continuously, some substance such as lime may be added to neutralize the hydrochloric acid carried over on the fruit and to render insoluble the arsenic remaining on the fruit after washing. Lime water can be made up by preparing a stock solution of "milk of lime" by slaking 1 pound of fresh quicklime and adding water to make it up to 1 gallon. Usually 1 gallon of this solution added to 50 gallons of rinse water is sufficient. If preferred, hydrated lime can be added directly at the rate of 1½ or possibly 2 pounds to 50 gallons of rinse water. Broken limestone placed directly in the rinse tank may also be used, but is less effective. Lime so used does not leave a conspicuous or undesirable residue. This method does not provide the desirable flushing off of fungus spores, and the process must be carefully watched to see that the lime does not become exhausted by the acid that is constantly being carried over.

Mere rinsing of the fruit in boxes in a tank, even if some fresh water is added, is generally not so satisfactory as the rinsing methods mentioned above. In washing machines the fruit should generally be exposed to the rinsing at least half as long as to the acid. Where alkaline washes are used the exposure in the rinsing section should be equal to that in the washing section. The operator should give constant attention to keeping the rinsing section in good operating condition. It is not necessary to titrate the rinse water with the reagents used for testing the acid in order to determine whether it is becoming acid; it is only necessary to taste the rinse water, as the tongue is sensitive to very small quantities of acid. If recirculated rinse water tastes very faintly sour, and there is an adequate fresh-water rinse at the end, no particular apprehension need be felt provided the water left in the stem or calyx ends of the fruit does not have an acid taste; but if the rinse water has a distinctly sour taste, steps should be taken immediately, either by supplying more fresh water or by adjusting possibly faulty equipment, to remedy this deficiency and so to protect the storage life of the fruit.

DRYING THE FRUIT

If sound fruit is used and if the washing and rinsing operations are carefully done, drying the fruit is not essential to protect its keeping quality, although it may be desirable in order to facilitate packing if fruit is to be wrapped and packed in boxes. In any event, traces of moisture do not impair the keeping quality of the fruit, and the moisture usually disappears entirely while the fruit stands in storage, especially if it is wrapped.

Where it is desirable to remove the adhering water from fruit that has been washed in a dipping tank or in a flotation paddle washer, the fruit may be allowed to dry in the containers after it is taken from the washing equipment. The rate of drying under atmospheric conditions will depend upon the temperature and relative humidity of the air and upon prevailing wind velocities, particularly if the containers are stacked in the open.

It is sometimes possible to remove some of the excess moisture after washing in the dipping or flotation paddle machines by passing the fruit through dry-cleaning equipment. In such cases the cloth wipers or the brush bristles should just touch the fruit, and the machine should be run fast enough to throw off the water droplets from the cleaners. If this is done, it will not be necessary to replace the cloths or brushes as often as when the machines are operated for dry cleaning. This operation is also effective in removing insect specking, dirt, and other residues that may not come off in the washing process. It may also give the fruit some degree of polish.

Several types of driers are used on commercial washing machines, and most of them are quite satisfactory in removing sufficient moisture to permit satisfactory packing and to safeguard the keeping quality of the fruit. Three general types are found:

One type employs an air blast, which actually blows the water off mechanically. No method of drying involving the evaporation of water has proved successful.

Another type causes contact of the fruit with either absorbent cloths or toweling which takes up the rinse water and from which the water is squeezed periodically by a rubber roller. This treatment is also effective in removing insect specking, dirt, and other residues not removed by washing.

The third type employs rotating cylindrical brushes alone or in combination with metal rollers designed to remove the water. In the latter case the fruit may be polished in the drying process. While it is not generally essential, some packers prefer this polish where a slight lack of luster is found on fruit that has been through the washer. Any additional handling such as occurs when fruit is passed through a polisher may increase the risks of injury and therefore should be well justified and tested before it is done.

EFFECT OF CLEANING METHODS ON KEEPING QUALITY

While dry cleaning of apples can be done on a commercial scale in such a manner that there will be no exceptional loss from decay or deterioration in storage, there is a greater risk of damage than when washing methods are used. Bruising; mechanical injury by dirty, waxy cloths or by conveyors in the equipment; spreading of decay contamination through microscopic cuts or injuries to the skin by the smearing action of the wipers; puncturing by bristles in brush cleaners—all these are possible where dry-cleaning methods are used.

The dry cleaning of pears is especially hazardous. This is particularly true of tender-skinned varieties such as Comice and Anjou, on which dry cleaning may produce skin scratches, abrasions, and stem punctures. The smaller pears are generally the most seriously affected, the injury being manifested as a dark discoloration of the skin accompanied by excessive wilting. This is due to abrasive action when the gritty "stone cells" located just beneath the skin are pounded by the wiping cloths or brushes.

The prevalence of rot is mainly dependent upon skin punctures and abrasions. The severity of these is, of course, determined by the character of the handling that the fruit receives.

Mature apples and pears can be washed satisfactorily with dilute hydrochloric acid under commercial conditions without serious injury to the fruit, if certain precautions are taken. These are generally simple and may prevent rather serious injury which might occur if the washing were carelessly done.

The possible injuries, which are considered in greater detail in the following paragraphs, may be classified as follows: Arsenical injury at the calyx or stem, hydrochloric-acid burning, alkali injury, chemical injury at the core, and heat injury.

Two general suggestions for avoiding trouble may be given in addition to those already mentioned. All decayed specimens should be sorted out before the fruit is washed, to prevent them from contaminating the washing and rinsing solutions. Fruit should not be left in the washing machines or dipping tanks during rest periods or when it is necessary to discontinue operation. This is especially imperative when warm cleaning solution is used.

Arsenical injury is usually localized in the calyx region, although occasionally it is found at the base of the stem and rarely on the cheeks. It appears as depressed black or dark-brown areas or spots and is sometimes followed by storage rots. The same type of injury has also occurred on heavily sprayed apples while still on the trees during rainy fall weather, but it is more common on picked apples that are allowed to stand unprotected from the rain. It has been observed on stored uncleaned fruit that was packed wet. Arsenical injury of this sort on uncleaned apples is apparently due to accumulation of soluble arsenic from the arsenical sprays applied. This injury starts when moisture is present. The same type of arsenical injury occurs when spray residue is not completely removed from the deep calyx region, the disintegration of the lead arsenate to form soluble arsenic salts apparently beginning in the washing process and continuing under the influence of solvents or moisture retained on the fruit.

Reasonably thorough removal of the spray residue, proper rinsing, and consistently changing the acid solution at the intervals already suggested will protect fruit against this trouble. The use of a final fresh-water rinse as the fruit leaves the washing machine is also essential for removing traces of soluble arsenic.

The addition of lime to the rinse water as a precautionary measure has been mentioned and may be desirable under certain conditions. The lime not only neutralizes the acid solution left on the fruit but also converts the soluble arsenic remaining on it into a form relatively insoluble and noninjurious to fruit.

Hydrochloric-acid injury is distinguished from arsenical injury primarily by its lighter color and by its occurrence on any portion of the fruit surface rather than being confined principally to the calyx end. The injured parts usually have a bleached appearance, frequently accompanied by cracking through the center of the area. The injured areas or spots may also become depressed with age, and sometimes the presence of soluble arsenic causes portions of them to turn black.

Prolonged exposure to the acid solution and too high concentration of the acid increase the risk of injury. Inadequate rinsing or neglect of rinsing will almost surely bring about acid injury to the fruit, although traces of acidity resulting from carry-over, as already mentioned, may be present in the rinse water without producing acid injury, provided a final fresh-water rinse is applied. Hydrochloric-acid injury is really caused by neglect or carelessness and generally is not an important factor in commercial operations.

Alkaline solvents are difficult to rinse off and may cause arsenical injury. Furthermore, apples washed with alkaline solvents may show a superficial brownish deposit in the calyx basin, apparently the effect of the alkali on the pubescence in the calyx.

Occasionally the alkaline solution itself causes chemical injury around the stem or the calyx and sometimes at the lenticels as well. It is shown by the effect on the skin, which in the case of apples becomes dry and papery, tightly stretched but seldom cracked, and is often torn loose from the underlying fleshy tissue. The color is yellowish or brownish yellow, except when a considerable quantity

of soluble arsenic is present, in which case the color becomes dark brown or black. Alkali injury on pears is most often shown by dark spotting at the lenticels. Very careful rinsing will reduce this form of injury to a minimum and should make it of no practical significance, except on pears, for which the use of alkaline washes is not recommended.

In some of the early types of washing machinery involving deep submersion of the fruit or the application of the solution in direct jets, some injury was caused by the penetration of the solvent into the core through open calyx tubes. Submersion to a depth of 4 to 6 inches may also result in penetration in some cases. This chemical injury is frequently followed by decay at the core. Open calyx tubes are more prevalent in certain varieties of apples and in very large fruit.

When apples are submerged in solutions warmed to 100° F. or higher for periods of three minutes or longer there is considerable danger of their injury. The results of such injury usually appear within 10 days or two weeks, in the development of cracks around the calyx, often continuing on to the cheek; or the injury may appear soon after washing in the form of numerous cracks scattered over the surface of the apples, particularly if a relatively high acid or alkali concentration has been used in the washing solution. The cracked skin is usually grayish or yellowish in color, resembling hydrochloric-acid injury, but is blackened if considerable soluble arsenic is dissolved in the cleaning solution. Apples are somewhat more susceptible to this type of injury at the time of harvest than after being kept for several weeks. None of the successful commercial washing machines requires exposure of the fruit for a period long enough to cause heat injury, but there is some danger of such injury when homemade washing equipment is used.

By keeping the temperature of the cleaning solution at 100° F. or below and preventing excessively long exposure to warm acid, danger of heat injury can be eliminated.

Aside from the rots which may follow penetration of the cleaning solution into the core, or those occurring as a result of chemical or heat injury, loss from storage rots may be somewhat greater on washed fruit owing to the extra handling to which it is subjected. The most important factor in preventing loss from storage rots is careful handling of the fruit to avoid bruising or puncturing the skin. The hazard can also be reduced by drenching the fruit with copious quantities of fresh rinsing water as it leaves the washing machine.

It is the general conclusion of those familiar with the removal of arsenical spray residue from apples and pears that if the washing is done with proper equipment and with proper care, under desirable sanitary conditions, neither the market value nor the keeping quality of the fruit will be impaired; on the contrary, both are frequently enhanced.[2]

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[2] For further information on the relation of washing operations to fruit injuries, the reader is referred to Technical Bulletin 245, Arsenical and Other Fruit Injuries of Apples Resulting from Washing Operations, issued by the United States Department of Agriculture.

TYPES OF WASHING EQUIPMENT

If large quantities of fruit are to be cleaned under commercial conditions, it is generally advisable to purchase a commercial washing machine. These may be obtained in capacities ranging from about 400 to 3,000 boxes or bushels per day. Their cost will vary with the location and installation, but may be expected to range from about $700 to $1,800 without freight charges. Information

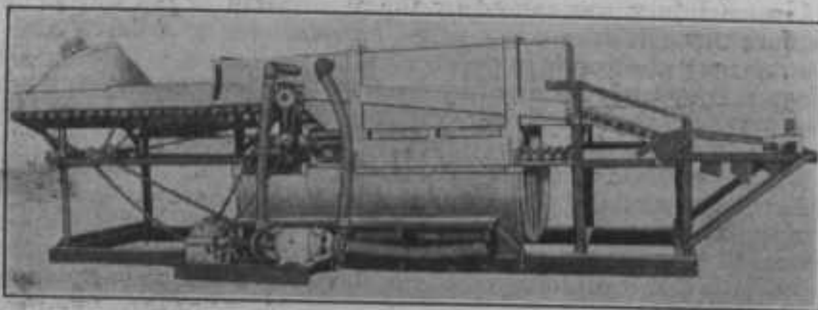

FIGURE 3.—A commercial fruit-washing machine

about them may be obtained directly from their manufacturers. Two types of commercial machines are shown in Figures 3 and 4.

Where smaller quantities of fruit are to be handled, as by a grower washing his own crop, two types of washing equipment, the paddle washer and a pair of dipping tanks, have been successfully used for several years. The following paragraphs describe the construction and operation of such equipment. The total cost, of course, will

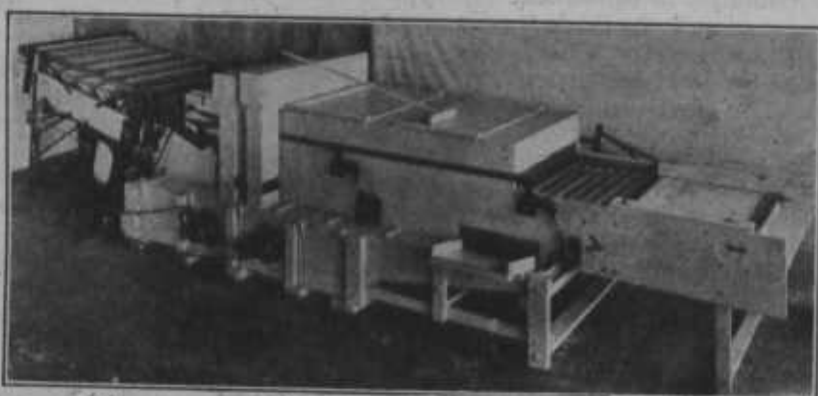

FIGURE 4.—Another type of commercial washing machine

vary with local differences in cost of material and labor and may be reduced by using idle pieces of machinery or equipment often found on the farm.

PADDLE WASHER

A power-driven fruit washer, simple enough in construction and low enough in cost to be practical for the grower with a small fruit tonnage, is shown in Figure 5. Plans for its construction are given in Figures 6 and 7. This machine is a modification of the citrus

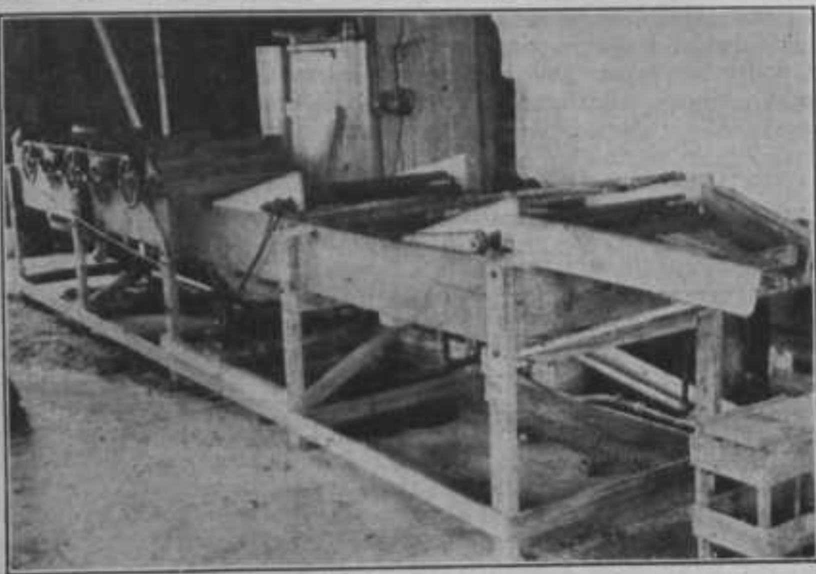

FIGURE 5.—Modified paddle washer

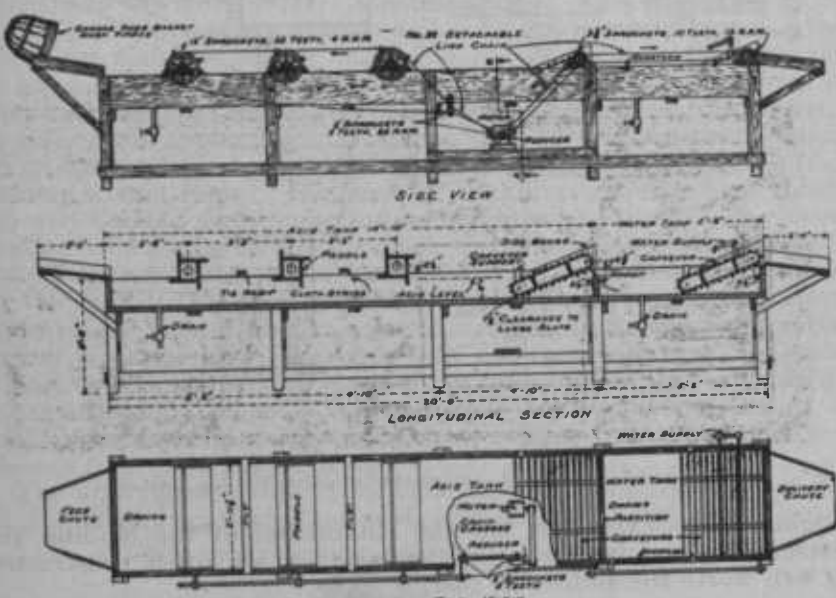

FIGURE 6.—Drawings of modified paddle washer

washer designed by the United States Department of Agriculture in 1925, and differs from the adaptation of that washer by the Oregon Agricultural Experiment Station (Circular of Information No. 15) in using conveyors instead of paddles to take the fruit from the tanks. Short lengths of conveyors in place of lift paddles are

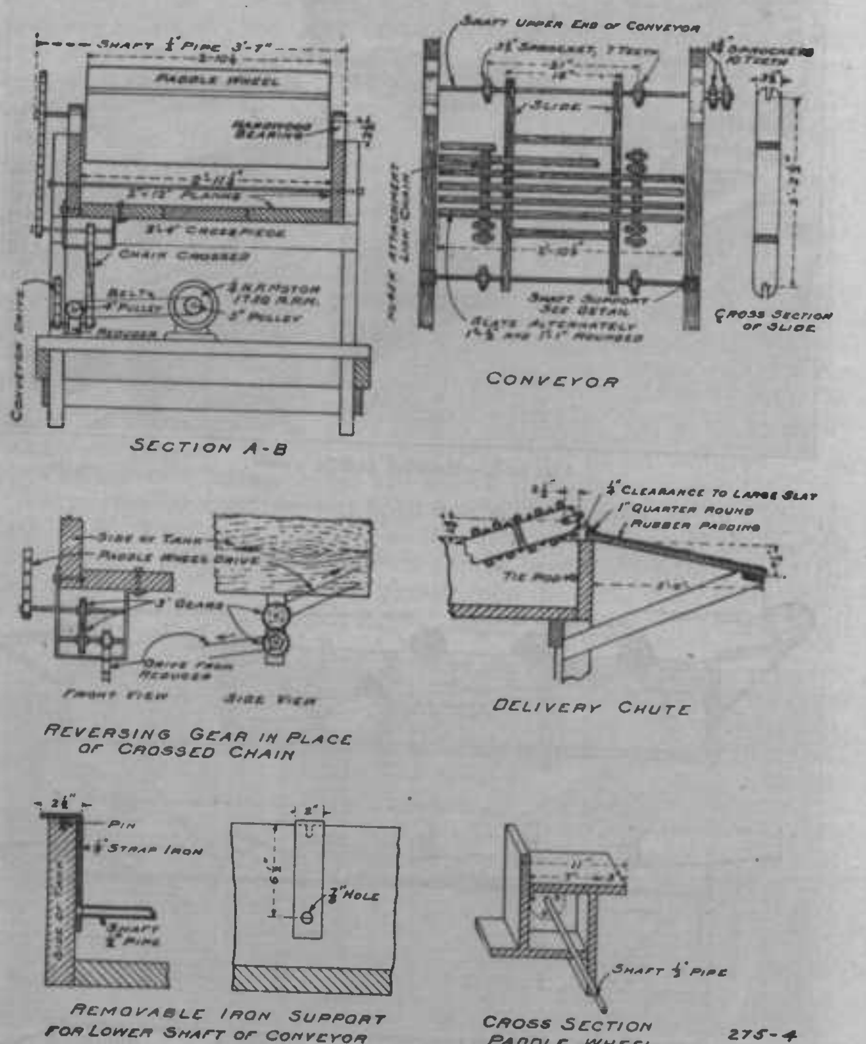

FIGURE 7.—Details of construction of modified paddle washer

slightly more expensive, but the elimination of the binding and catching caused by these paddles, as they are often constructed, is well worth the additional cost.

CONSTRUCTION OF CONVEYORS

Paddle-type washers can be easily modified by removing the lift paddles and installing the lengths of slatted conveyors shown in the

plans. The width of the conveyors will depend upon the inside dimensions of the tank. The drive for the conveyors will obviously have to be in the reverse direction from that used for the paddles, but this change can be accomplished by using a pair of reversing gears or by crossing the chain as indicated in the drawings in Figure 7. The conveyor shown is about the shortest that will satisfactorily remove the apples from the tank. Machine bolts, nuts, and washers are desirable means of attaching the hardwood slats so that they can be removed easily. Iron bolts, nuts, and washers will last longer in the acid than those made of brass. If the sprockets for this part of the equipment, and the driving mechanism as well, can not be procured from the factory with the face of the teeth beveled to about 30°, they should be ground before installing. If the teeth are left square, the chain will hang to the sprockets, especially on the smaller sizes, resulting in a great deal of trouble in driving them. In making the slide around which the conveyor moves, a slot should be made for the upper shaft in the side boards, as indicated also in Figure 7, to facilitate putting the conveyor in place.

The distances from the center of the upper shaft to the top and to the end of the tank are important in delivering the fruit from the ends of the conveyors. These distances as shown should be 2¾ inches from the top and 4 inches from the end of the tank. A piece of automobile tire inner tubing stretched at an angle from the end of the conveyor into the rinse tank will roll the fruit toward the end of the other conveyor and thereby reduce the chances of its being bruised by falling from the end of the conveyor on to fruit floating beneath in the rinse water. A chute made of ⅞-inch boards resting on a ⅞-inch crosspiece that is nailed to the top of the tank gives about the right height for delivering the apples from the conveyor. A piece of 1-inch quarter-round molding nailed across the end of the chute, clearing the largest cleat by a quarter of an inch, will aid in rolling the apples from the end of the conveyor with a minimum of bruising. A pitch of about 2½ inches in 2 feet will keep the fruit rolling on the chute. The piece of molding and the chute should be well padded with inner tubing or other material. The lower shaft of the conveyor is hung from the sides of the tank with iron stripping and held in place by pins which fit into holes in the sides of the tank. This method of holding the conveyors enables them to be raised from the tanks when not in use, thus reducing the corrosion from the acid and water, and facilitates cleaning the tanks. The clearance from the bottom of the tank to the large slats on the conveyor should be about one-half inch. A conveyor speed of 10 to 15 feet per minute will remove the fruit from the tanks fast enough to prevent its piling up.

The approximate cost of material for one conveyor is about $12 to $14, including chain, sprockets, slats, screws, and shafts.

CONSTRUCTION OF TANKS AND SUBMERGER PADDLES

The tanks are conveniently made of 2 by 12 inch material, with the acid tank 15 feet and the rinse tank 5 feet long, making a length over all of about 24 feet, including both feeding and delivery chutes. The machine described is only three boards wide, but if a larger

capacity is needed, adding one or two boards to the width will increase the cost only slightly and will increase the capacity one-third and two-thirds, respectively. By using bolts and cross braces, as indicated in Figure 7, the tank can be drawn together. The edges of the boards should be first painted with asphalt paint to give tight seams. If the inside of the tank is painted, asphalt and not lead paint should be used, as the acid attacks lead. The shafts for the conveyors and submerger paddles are made of ½-inch pipe. Electrical conduit pipe is slightly cheaper than regular black iron or galvanized-iron pipe. This dimension refers to the inside diameter of the pipe, the external diameter being slightly less than seven-eighths of an inch. The shafts for the submerger paddles and those for the driving end of the conveyor are 43 inches long. A convenient and economical way to fasten the submerger paddles to the shaft is with floor flanges for rail fittings, which are procurable at any plumbing shop. Those made for ¾-inch pipe will fit over the ½-inch pipes and can be fastened to them by driving a pin in a hole drilled through the collar of the flange and the pipe.

The machine as shown is 42 inches high. This height is adapted to the usual height of graders, but the tank may be somewhat high if the fruit is dumped into it by hand. The capacity of the acid tank in the machine constructed according to the accompanying plans is about 210 gallons when filled to the recommended depth of 8 inches, while the rinse tank holds about 70 gallons. The fresh-water spray on the end conveyor is a very important feature and should supply from 2 to 3 gallons of fresh water per bushel or box of fruit washed. The cloth strips hung across the rinse tanks should preferably be made of heavy cloth and should be about 2 inches wide and long enough to allow about 3 inches to hang on the fruit as it is floated through the tank, thus turning it as the cloths cling to the apples while they move. These strips add to the efficiency of the machine by giving the fruit a longer and more complete exposure to the acid and are of some value in removing insect specking, dirt and lime-sulphur residue.

DRIVING MECHANISM

The sprockets, pulleys, and speeds shown in the plans are based upon a motor speed of 1,750 revolutions per minute with a 60-cycle current. If a 25-cycle current is used, giving 1,450 revolutions per minute motor speed, approximately the same speeds can be obtained with the driving mechanism shown by using a 3½-inch pulley on the reducer instead of a 4-inch pulley. A ¼-horsepower motor has been found large enough to run this machine. The reducing gear used, although smaller than recommended, transmitting only one-sixteenth horsepower, gave no signs of wear in a test run of about a month. A larger unit equipped with ball or roller bearings and transmitting one-fourth horsepower would provide a desirable margin of safety in operating the machine season after season. The gears and bearings must be kept well oiled. While the reduction in speed can be made by using a combination of sprockets or pulleys, the reduction gear will be about as economical when the installation of extra shafts and the cost of the additional gears or sprockets are

considered. The diameter, the number of teeth, and the speed of the sprockets and pulleys are shown in the plans. The change in speed produced by the use of different sizes of sprockets or pulleys is of course in proportion to the number of teeth or in proportion to the diameters of the pulleys. The specifications and approximate cost of the driving equipment are given in the list of materials. No. 32 chain is used for driving, while the conveyor chain is No. 45–K–1 attachment link chain. All sprockets are equipped with set screws instead of keys.

If a gasoline engine is used as a source of power, a combination of sprockets or pulleys can be used to obtain the proper speed reduction.

CAPACITY

When built according to the accompanying specifications, the machine has a capacity of about 80 bushels an hour when the fruit is left in the acid solution for three to four minutes, which is about the desired time for most fruit. If the fruit is fed into the machine faster, more can be washed in a given time, the rate of feeding regulating the time in the acid and the resulting capacity. Increasing the speed to more than 80 bushels an hour is not recommended, and the machine should be built wider if it is anticipated that this capacity will not suffice.

COST

The material and equipment for the entire paddle-washer machine will cost about $100, including the motor and reducing gear. One carpenter should be able to build the tank and submerger paddles in about three days. The time necessary for putting the conveyor together and installing the driving mechanism will depend upon the mechanical ability of the individual, but the mechanism is simple enough to offer no great difficulty if the specifications are followed.

LIST OF MATERIALS

Lumber

5 pieces 2 by 12 inches by 20 feet long, for tank sides and bottom.
3 pieces 2 by 12 inches by 3 feet long, for tank ends and partition.
10 pieces 2 by 4 inches by 3 feet 6 inches long, for legs.
8 pieces 2 by 4 inches by 3 feet 7 inches long, for cross braces to tank.
4 pieces 1 by 4 inches by 10 feet long, for bottom leg braces.
2 pieces 1 by 4 inches by 3 feet 7 inches long, for bottom leg braces.
5 pieces 1 by 4 inches by 4 feet 4 inches long, for cross braces for legs.
4 pieces 1 by 4 inches by 2 feet 6 inches long, for conveyor slides.
2 pieces 1 by 4 inches by 3 feet 7 inches long, for holders for cloth strips.
12 pieces ⅞ by 10 inches by 2 feet 10 inches long, finished, for submerger paddles.
4 pieces 1 by 6 inches by 2 feet 6 inches long, for conveyor guards.
6 pieces 1 by 6 inches by 6 inches long, for submerger paddle ends.
10 pieces 2 by 4 inches by 4 inches long, hardwood, for bearings.
40 pieces 1 by 1 inch by 2 feet 10 inches long, hardwood, for conveyor slats.
40 pieces 1 by ½ inch by 2 feet 10 inches long, hardwood, for conveyor slats.

Total cost of lumber (Washington, D. C., prices) $17.00

Hardware, etc.

½-inch tank bolts, 3 feet 7 inches long, 3 at 35 cents	$1.05
Pipe for shafting, 3 feet 7 inches long, 5 pieces at 6 cents a foot	1.08
Pipe for shafting, 2 feet 11 inches long, 2 pieces at 6 cents a foot	.35
Pipe for shafting, 10 inches long, 1 piece at 6 cents a foot	.05
¾-inch cast-iron pipe flanges, 6 at 6 cents	.36
No. 8–32 iron machine screws, 1 inch long, 2 gross at 75 cents	1.50
No. 8–32 iron machine screws, 1½ inches long, 2 gross at 95 cents	1.90
Washers for screws	.25
Driving mechanism:	
No. 32 detachable driving chain, 50 feet at 10 cents a foot	5.00
No. 45–K–1 attachment link chain for conveyor, 22 feet at 25 cents a foot	5.50
Sprockets:	
For No. 32 chain, solid, set screw—	
12-inch sprockets, 33 teeth, ⅞-inch bore, 3 at $3.25	9.75
3¾-inch sprockets, 10 teeth, ⅞-inch bore, 3 at $1.75	5.25
2-inch sprockets, 5 teeth, ⅞-inch bore, 3 at $1.35	4.05
2-inch sprockets, 5 teeth, ½ or ¾ inch bore, depending on size of reducer driving shaft, 2 at $1.35	2.70
For No. 45–K chain, solid, set screw—	
3½-inch sprockets, 7 teeth, ⅞-inch bore, 8 at $1.70	13.60
Speed-reduction gear, 48–1 or 50–1 reduction with 4-inch or 3½-inch pulley, depending on motor speed of 1,750 or 1,450 revolutions per minute, respectively; cost $14 to $40, depending on size and make	25.00
Total estimated cost of material and equipment	94.39

The speed-reduction gears of the larger size have driving shafts of ¾-inch diameter, while the size transmitting one-sixteenth horsepower has a ½-inch driving shaft. In ordering the sprockets for this part of the driving mechanism, the specification of their bore should not be overlooked.

The chain, sprockets, and speed-reduction gears can usually be obtained through a local dealer in hardware or farm machinery. Because of possible delays in getting the material shipped and difficulties that may arise in making the machine, orders should be placed in ample time and the construction of the machine begun some time in advance of the packing season.

DIPPING TANKS

Dipping tanks are fairly satisfactory as homemade devices for washing pears. They are not recommended for apples except in an emergency when fruit must be washed quickly and no other equipment is immediately available or if a grower has only a small quantity of apples to wash. The paddle washer previously described is recommended as a homemade washer for apples. The saving in labor and the additional margin of safety that it provides more than compensate for its slightly greater cost.

If a considerable proportion of the apples have open calyx tubes, dipping tanks are not recommended unless they are modified to include an overhead spray or sluicing of liquid which makes it possible to lower the level of the liquid in the tanks.

As shown in Figure 8, the dipping tank installation consists of two similar tanks, one used for the acid solution and the other for the rinsing bath. Putting the tanks together with a spline is an excellent method of making them waterproof. Since the edges of the boards must be finished, the grooves can be cut at the mill with

little extra cost. Three-eighths-inch bolts are used to draw the tanks together; they are fastened through the legs below the tank for the horizontal pressure and through 2 by 4's across the top and bottom of the tank for vertical pressure. Asphalt paint should be used on all seams and joints, because it is acid-proof as well as waterproof.

The drain board should slope toward the acid-solution tank. Its floor is made of pieces 1 by 6 inches, laid flat. Strips 1 by 2 inches are nailed lengthwise on this floor every 6 inches, so that the liquid will flow back freely into the acid-solution tank. A similar drain board can be made at the end of the rinse tank, long enough to accommodate at least two boxes. The slides at the ends of each tank aid in getting the boxes into and out of the tanks and are conveniently made of pieces 2 by 4 inches, laid on edge.

Some device for slightly submerging the boxes of fruit as they pass through the tanks will obviate the necessity of doing it by

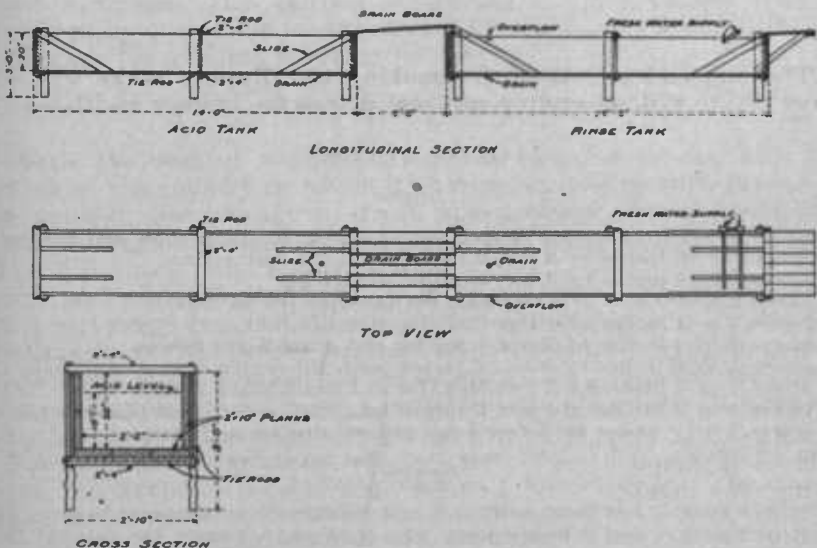

FIGURE 8.—Dipping tanks

hand. Two boards can be placed lengthwise in the tanks at the acid-solution level, and if fastened to the crosspiece at the feeding end of the tank by means of hinges their weight will suffice to keep the boxes slightly submerged as they are pushed through. When the modification of the dipping tank described in a following paragraph (p. 30) is used, with an overhead spray or sluice of liquid on the fruit, submerging the boxes in the acid solution is obviously not necessary.

Ordinary apple boxes with slatted sides and fitted with easily removable covers are good containers to use in the tanks. If the washing is done in the picking boxes or lugs, extra handling of the fruit is eliminated, thus reducing the labor required and minimizing the danger of injury to the fruit. If covers are used, they should be removed when the boxes or lugs reach the end of the rinse tank, where the fresh-water spray is located.

An exposure of from three to five minutes in the acid-solution tank and a similar period in the rinse is recommended for cleaning lots of fruit bearing average amounts of spray residue. The depth of the liquid in the tank should be about 15 inches when the tank is filled with boxes of fruit. Fresh water should flow into the rinse tank by means of a spray or should flood over the fruit as it leaves the rinse tank. From 2 to 3 gallons of fresh water should be supplied for every box of fruit washed.

CAPACITY

The dipping-tank equipment described has a capacity of more than a carload a day, allowing for an exposure of each box of fruit for three or four minutes in the cleaning solution and the same period of time in the rinse tank.

COST

The material and labor for making the dipping tanks will cost from $30 to $70, depending on local prices for lumber and labor.

LIST OF MATERIALS

Lumber

14 pieces 2 by 10 inches by 14 feet long, finished, for tank sides and bottom.
8 pieces 2 by 10 inches by 2 feet 2 inches long, for tank ends.
12 pieces 2 by 4 inches by 3 feet long, for tank legs.
12 pieces 2 by 4 inches by 3 feet long, for cross braces on tank.
8 pieces 2 by 4 inches by 4 feet long, for slides in tank.
2 pieces 2 by 4 inches by 3 feet long, for end drain-board braces.
6 pieces 1 by 6 inches by 4 feet 6 inches long, for center drain-board floor.
6 pieces 1 by 6 inches by 3 feet long, for end drain-board floor.
7 pieces 1 by 2 inches by 4 feet 6 inches long, for center drain-board strips.
7 pieces 1 by 2 inches by 3 feet long, for end drain-board strips.

Hardware

6 ⅝-inch rods, 3 feet long, with nuts and washers, for horizontal tank braces.
12 ⅝-inch rods, 2 feet 2 inches long, with nuts and washers, for vertical tank braces.
1-inch pipe for fresh-water spray.

MODIFICATIONS

If it is more suitable to the packing operations the tanks can be set up beside each other instead of end to end, and the drain board can be placed across their ends.

Pumping the acid solution into pipes or a sluice box over the washing tank and letting it flow over the fruit, mostly by gravity, has been found particularly helpful in increasing cleaning efficiency where electric power is available to operate the pump. This method combines a dipping treatment with a modified spray or flood wash. A small centrifugal pump such as is used for filling spray tanks will serve the purpose.

Where pipes are used, holes may be bored in them to allow the solution to flow over the fruit, or nozzles of various forms may be used. Where the sluice box is employed, slots or holes bored in its bottom will serve the purpose. In either case a screen should be

placed over the pump intake so that leaves, twigs, and sediment in the washing solution will not clog the pump or the openings for the liquid. An important advantage of this modification of the dipping tank is that pumping the liquid out of the tank and directing it over the fruit reduces the depth of the cleaning solution in the tank and thus lessens the danger of core penetration by the solution, without sacrificing any cleaning efficiency.

Moving the boxes of fruit through the tanks has been facilitated by using ordinary roller conveyors, the acid solution not affecting them enough to prohibit their use. Belt conveyors driven by electric motors also have been used to carry boxes through the tanks.

Another modification of the dipping tank has been made by increasing the width of the tank to give room for the installation of power-driven longitudinal paddles which throw acid into the boxes of fruit as they are pushed through on roller conveyors submerged about 8 inches. This method of getting the acid on the fruit is employed by one of the manufactured machines, and application has been made for a patent covering its use.

COST OF REMOVING SPRAY RESIDUE

While the cost of washing fruit will vary, of course, with the section of the country in which it is done, as well as with the washing method, the tonnage of fruit, the packing arrangements, and the character of the spray residues on the fruit, it may be helpful to indicate such costs approximately.

In the Pacific Northwest the cost of washing a box or bushel of fruit will range from 1 to 2 cents for hand dipping in small lots and 2 to 3 cents for the paddle washer to 3 to 4 cents for washing moderate tonnage in the commercial machines, with a proportionate reduction per box as the tonnage is increased and the overhead costs are distributed over a greater number of boxes.

Under eastern conditions the cost per bushel has generally been from 1 to 5 cents, with 2 to 2½ cents as a fair average. The cost of washing decreases as the amount of fruit handled increases; it also depends on the initial cost of the machine. The cost of washing 5,000 bushels with a small commercial machine would be about 5 cents a bushel, 2 cents with a paddle washer, and 2¾ cents for hand dipping. For 15,000 bushels the costs per bushel would be about 2¼ cents for the commercial machine, 1 cent for the paddle washer, and 2½ cents for hand dipping. Except in the case of hand dipping, the cost of labor is not materially increased because of washing. In arriving at the foregoing estimates, interest and depreciation on the investment, maintenance, and cost of water, power, and materials were considered.

While no actual cost estimates for dry-cleaning fruit are available, such figures as have been calculated from time to time have indicated that washing fruit is a more economical as well as a more efficient method of removing arsenical spray residues from apples and pears.

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